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METHOD FOR MANUFACTURING A CLEANED STEEL ACCOMPANIED BY MINIMAL NON-METALLIC INCLUSIONS
[Hikinzoku Kaizaibutsu no Sukunai Seijo Ko no Seizo Ho]

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1. Title of the invention

Method for manufacturing a cleaned steel accompanied by minimal non-metallic inclusions

2. Patent Claims

1. A method for manufacturing a cleaned steel characterized by an attempt, by adding, to an aluminum-deoxygenated or aluminum/silicon-deoxygenated molten steel, 0.001 ~ 0.05% of one, two, or more types of molten steel surface activators selected from among Se, Sb, La, & Ce with respect to said molten steel, to minimize non-metallic inclusions consisting principally of an alumina cluster.

2. A method for manufacturing a cleaned steel characterized by an attempt, by adding, to an aluminum-deoxygenated or aluminum/silicon-deoxygenated molten steel, 0.001 ~ 0.05% of one, two, or more types of molten steel surface activators selected from among Se, Sb, La, & Ce with respect to said molten steel in a state where said molten steel is being agitated during or after the addition of the same, to minimize non-metallic inclusions consisting principally of an alumina cluster.

3. Detailed explanation of the invention

The marrow of the present invention lies in an attempt, by adding, to an aluminum-deoxygenated or aluminum/silicon-deoxygenated molten steel, one, two, or more types of molten steel surface activators selected from among Se, Sb, La, & Ce, to facilitate the flotation & separation of non-metallic inclusions within said molten steel consisting principally of a colonized alumina inclusion (alumina cluster), and it concerns a method for manufacturing, by agitating the molten steel during or after the addition of the aforementioned element(s) and by thus facilitating further the flotation & separation of the aforementioned non-metallic inclusions, a method for manufacturing a cleaned steel accompanied by minimal non-metallic inclusions.

The following methods have, in the prior art, been practiced on occasions for manufacturing cleaned steels by using aluminum killed or aluminum/silicon killed steels:

(i): A method wherein a forcible deoxygenating agent capable of generating inclusions bearing favorable flotation & separation tendencies is selected & used;

(ii): A method wherein inclusions are removed by inducing the adhesion thereof to a refractory matter bearing a high affinity therewith; and

(iii): A method wherein flocculation, flotation, & separation are accelerated by means of forcible agitation (e.g., electromagnetic inductive agitation, gas bubbling, agitations by means of DH & RH, etc.). /2

Fair effects have, furthermore, been yielded by the aforementioned respective methods.

Japanese Patent Application Publication Kokai No. Sho 49[1974]-128815, on the other hand, proposes a method for obtaining a cleaned steel accompanied by a minimal alumina cluster by adding, at an appropriate quantitative ratio, S to a deoxygenating agent, whereas Japanese Patent Application Publication Kokai No. Sho 49[1974]-39510 proposes a method for manufacturing a cold-rolled steel sheet bearing excellent surface properties by adding, at an appropriate quantitative ratio, S within a pot or cast, whereas each represents an attempt to separate an Al_2O_3 cluster by adding S to a molten steel. An S content gain within a steel, however, is undesirable in that it causes the following troubles related to product & slab qualities:

(I): The mechanical properties of a steel product deteriorate;

(II): The red heat embrittlement of a slab or hot-processed (e.g., hot-rolled, etc.) material becomes accelerated, resulting in a yield loss;

(III): A method for upping the Mn/S ratio is known for the purpose of preventing the phenomenon of the aforementioned item (II), although since the draw processibility deteriorates as a result of this measure, it is especially inappropriate for cold-rolled steel sheets;

(IV): Unlike the formation of an ordinary ingot, hot water finish adjustments, etc. cannot be applied to continuous casting, and therefore, in a case where the S content of a steel becomes 0.025% or higher, surface scars such as lengthwise cracks, etc. proliferate, which is undesirable in that additional retouching becomes necessary and that a yield loss becomes incurred;

(V): The aforementioned pair of proposed techniques cannot be applied to a case where the S content of a molten iron is high due to the respective phenomena of the aforementioned items (I) ~ (IV), and therefore, it is necessary to add S by blowing a molten iron which has been preliminarily desulfurized.

The objective of the present invention, which has been conceived for the purpose of solving these problems, is to provide a cleaned steel by adding a trace of a molten iron surface activating element(s) to a molten steel or by combining this additive(s) with an agitation mechanism for inducing the flotation, separation, & removal, from said molten steel, of non-metallic inclusions consisting principally of an alumina cluster.

Next, the constitution of the method of the present invention for manufacturing a cleaned steel will be explained; attempts are made, by adding 0.001 ~ 0.05% of a surface activating element(s) capable of exerting surface activating effects on molten iron (e.g., Se, Sb, La, Ce, etc.) to a molten steel which has been aluminum-deoxygenated or aluminum/silicon-deoxygenated based on an ordinary method, not only to induce the flotation & separation of non-metallic inclusions consisting principally of an alumina cluster but, by agitating said molten steel either during or after the addition of said surface activating element(s) and by thus further facilitating the flotation & separation of said non-metallic inclusions, also to obtain a cleaned steel accompanied by minimal non-metallic inclusions,

It is desirable for the molten steel temperature of a stage where said additive(s) is added to said molten steel to be at least 1,570°C, whereas it goes without saying that the targeted objective can be achieved by adding only one type of the aforementioned surface

activating elements such as Se, Sb, La, Ce, etc., although it has been verified by experiments conducted by the present inventor that, in a case where a composite of two or more types is added, it is more effective since their functions become synergistically upgraded. The lower limit on the addition ratio of the aforementioned surface activating element(s) is set at 0.001%, for in a case where the addition ratio is lower than this threshold, it becomes impossible to achieve the targeted objective due to minimal flotation & separation of the aforementioned inclusions, whereas the upper limit is set at 0.05%, for in a case where the addition ratio exceeds this threshold, the effects become saturated, accompanied by cost appreciation as well as by degradations of steel properties. Incidentally, the surface activating element(s) may bear any shape selected from among powders, grains, bars, lines, masses, and bullets, whereas they may also be alloyed or mixed with other alloying agents. The addition method may be predicated on either human or mechanical means, whereas it is desirable for the addition timing to coincide with abiding within a pot, DH or RH bath, or TD, although effects are also acknowledged within a cast as well.

Moreover, the agitation is executed for inducing homogeneous & prompt manifestations of the surface activating functions of the additive elements by dispersing the same effectively within the molten steel, whereas, on the other hand, effects of preventing the persistence of yet-to-be-melted component, of preventing localized deposition, and of accelerating the flotation of generated inclusions are concomitantly exerted. Moreover, the extent of agitation should be adventitiously adjusted depending on the molten steel temperature & volume, and although it is normally desirable for the duration of agitation to be at least 3 min., an excessive drop of the molten steel temperature is undesirable from the standpoint of securing the aforementioned functions, whereas since said effects also become saturated, the duration should be limited to 10 min. or less. All conceivable ordinary means of agitation such as electromagnetic inductive agitation, gas bubbling, DH, RH, etc. are effective as agitation mechanisms. /3

Next, the effects of the present invention will be demonstrated by citing application examples of the manufacturing method of the present invention together with comparative examples instantiating manufacturing methods of the prior art.

Example 1

A low-carbon steel was melted by using a 250 ton converter, and after it had been Al-deoxygenated within a pot at the time of the exit of said steel, an Al killed steel was obtained.

In a comparative example, a slab was manufactured by means of continuous casting after an Ar bubbling period of approximately 5 min. according to ordinary procedures. In Application Example 1, continuous casting was executed without recourse to gas bubbling after the addition, at a 0.005% equivalent, of Se to a molten steel at the pot deoxygenating stage. In Application Example 2, the aforementioned molten steel of Application Example 1 prevailing upon the completion of the addition of Se was subjected to Ar gas bubbling for approximately 5 min. and then continuously cast. In Application Example 3, the addition, at a 0.005% equivalent, of Sb to a molten steel at the pot deoxygenating stage was followed by an Ar gas bubbling period of 5 min. and then by continuous casting. Upon the completion of casting, slab whole cross-sectional S prints were collected from three sites along the draw widthwise directions, from normal positions, of the respective slabs, and alumina clusters were quantified for rendering alumina cluster evaluation scores (smaller numbers of evaluation scores are more favorable).

Incidentally, the method for evaluating & grading the alumina cluster was predicated on the following formula: {(cluster total area/slab cross-sectional area) $\times$ 100} $\times$ 1000 (in the above, cluster area = ? D^2, $D = (d_1 + d_2)/2$; d_1 = cross-sectional length of cluster; d_2 = cross-sectional width of cluster). The obtained results are shown in Table I below.

Table I

	Comparative Example	Application Example 1	Application Example 2	Application Example 3
Charge number	10	2	2	2
Molten steel weight	250 ton			
Converter terminal point components	S = 0.08±0.003%, Te = tr, Se = tr, & Sb = tr			
Addition ratios of surface activating elements	No addition	0.0005% of Se	Same as left	0.005% of Sb
Inert gas bubbling	Ar gas blow for 5 min.	No gas bubbling	Ar gas blow for 5 min.	Same as left
Steel type	Aluminum killed steel for cold-rolled steel sheet			
Continuous casting	Molten steel temperature within TD: 1,580°C; casting rate: 1.2 m/min.; slab cross-sectional area: 220 × 950			
Alumina cluster evaluation store	150±30	80±20	10±5	50±10

Example 2

In the aforementioned Example 1, surface activating elements were added at the pot deoxygenating stage, in contrast with which the experiment of the present example was conducted by changing only the surface activating element addition timing to the Ar gas bubbling stage under conditions otherwise identical to those in Example 1. In the

comparative example, Ar gas bubbling alone was executed, whereas in Application Example 4, 0.005% each of Se & Sb were wire-fed during Ar gas bubbling. The obtained results are shown in Table II below.

<u>Table II</u>

	Comparative Example	Application Example 4
Charge number, molten steel weight, converter terminal point components, steel type, & respective continuous casting conditions	Same as in Example 1	
Addition ratios of surface activating elements & inert gas bubbling	Ar gas bubbling alone	Addition, in linear forms, of 0.005% each of Se & Sb during gas bubbling of Ar for 5 min.
Alumina cluster evaluation score	150±30	10±5

It can be clearly gleaned from the aforementioned Table I & Table II that the /4 alumina clusters of cleaned steels manufactured by the manufacturing method of the present invention are mitigated far more effectively than in the manufacturing methods of the prior art represented by comparative examples.

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6. List of attached documents

(1): Specification: 1 copy;

(2): Proxy letter: 1 copy

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